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Synthesis of a novel glycosphingolipid from the millipede, *Parafontaria laminata armigera*, and the assembly of its carbohydrate moiety into multivalent structures

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Abstract—A novel glycosphingolipid, β-D-Man*p*-(1→4)-[α-L-Fuc*p*-(1→3)]-β-D-Glc*p*-(1→1)-Cer, found in the millipede, *Parafontaria laminata armigera*, and multivalent derivatives of its carbohydrate moiety were synthesized. As the key step, the target glycolipid (**1**) was obtained through an inversion reaction at the 2-position of a β-glucopyranoside residue yielding a β-mannopyranoside. In addition, the synthesis of fluorescently labeled trimer and tetramer glycoconjugates (**2**, **3**) was achieved by iterative amide bond formation using a monomer unit (**24**).

Keywords: Glycosphingolipids; *Parafontaria laminata armigera*; Intermolecular nucleophile approach; Glycocluster

1. Introduction

In our continuing studies to elucidate the biological function of glycoconjugates, we have synthesized novel glycosphingolipids found in various invertebrates[1–6] that do not have gangliosides. A number of glycosphingolipids from a variety of invertebrate origins and related analogues have been synthesized and their influence on proliferation has been examined using mouse melanoma B16 cells. In these studies, the glycolipid, β-D-Man*p*-(1→4)-[α-Fuc*p*-(1→3)]-β-D-Glc*p*-(1→1)-Cer, which has been isolated from the millipede *Parafontaria laminata armigera*, has been observed to inhibit significantly cell proliferation (details will be reported elsewhere).

In a previous paper,[2] we reported the synthesis of this glycosphingolipid. The key reaction in that synthesis was a two-step glycosylation. The first step was the formation of an orthoester from two sugar moieties and the second step was the reductive cleavage of one of the orthoester C–O bonds leading to β-selective mannosylation. This earlier paper was the first report on the total synthesis of β-D-Man*p*-(1→4)-[α-Fuc*p*-(1→3)]-β-D-Glc*p*-(1→1)-Cer by this method. Among β-mannopyranoside syntheses, one approach is the so called intermolecular nucleophiles approach,[7–10] in which an inversion reaction at the 2-position of β-glucopuranoside yields a β-mannopyranoside. The strategy, which provides good yields, relies upon creating a highly reactive leaving group at the position that is to be inverted and then treating it with a strong nucleophile. The nucleophile causes S_N2 displacement and epimerizes the position on the carbohydrate ring. We report here the application of this approach for the synthesis of glycosphingolipid **1**.

It is known that oligosaccharide chains generally interact with their protein receptors in a multivalent fashion to overcome the inherently low affinity of monovalent carbohydrate–protein interactions. Therefore, the construction of a clustered glycoconjugates is an important subject in glycoscience.[11,12] For this reason, we have used a new method to synthesize new peptidic glycoclusters and glycodendrons (**2**, **3**), which consist of a β-alanine derivative linked to the sugar moiety of **1** (Fig. 1).[13,14]

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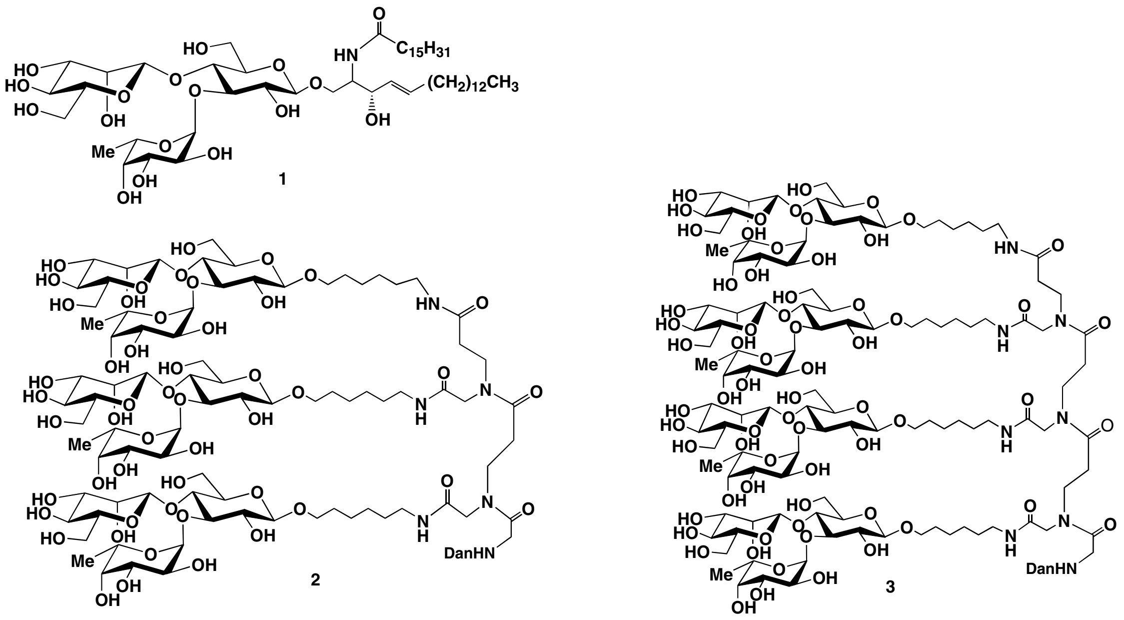


Figure 1. Structure of target glycoconjugates.

2. Results and discussion

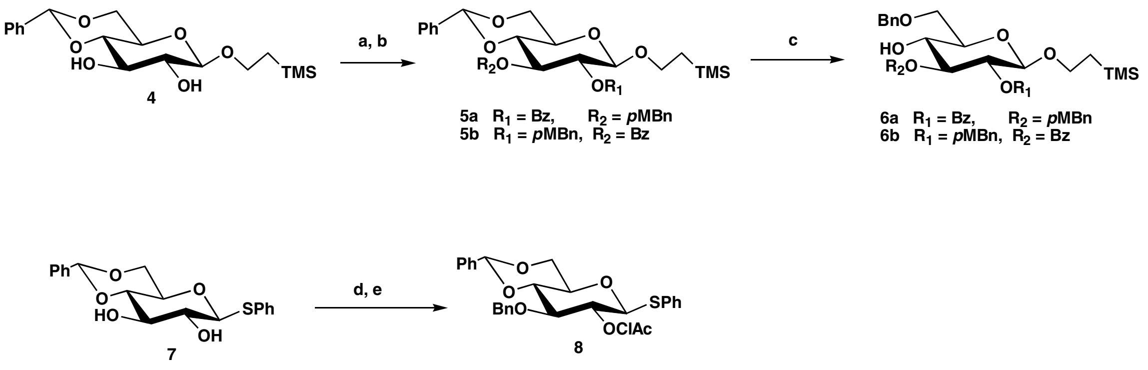
2.1. Syntheses of monosaccharide derivatives

Syntheses of the glucopyranose building blocks **6a** and **8** were carried out as depicted in Scheme 1. Compound **6a** was prepared from known 2-(trimethylsilyl)ethyl 4,6-*O*-benzylidene-β-D-glucopyranoside (**4**)[15] via successive mono-alkylation of the diol, acylation and reductive ring opening of the 4,6-acetal. Unfortunately, alkylation of **4** via a stanylene intermediate did not proceed in a regiospecific manner. Although the formation of dialkylated product was avoided, the two regioisomeric monoalkylated products could not be separated, nor could their benzoylated derivatives **5a** and **5b** be separated. The structures of **5a** and **5b** were confirmed after reductive ring opening of the benzylidene acetal in **5**, which yielded a 1.5:1 ratio of **6a** and **6b** in a combined yield of 72%.

Glucopyranosyl donor **8** was obtained from phenyl 4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside (**7**),[16] via a two-step procedure. First, reaction of the stannylidene derivative of **7** with benzyl bromide was found to be highly regiospecific in this case, which may be associated with the electron donating nature of the sulfur aglycon. Second, subsequent chloroacetylation of **7** afforded **8** (81% over two steps).

2.2. Synthesis of the target glycosphingolipid

Glycosylation of acceptor **6a** with **8** in the presence of *N*-iodosuccinimide (NIS), trifluoromethanesulfonic acid (TfOH),[17] and 4 Å molecular sieves in dichloromethane gave the desired disaccharide (**9**) in 57% yield after purification. The stereochemistry of the newly formed glycosidic linkage could be determined by ^{1}H NMR spectroscopy (H-1′, 4.61 ppm, $J = 7.9$ Hz). Selective

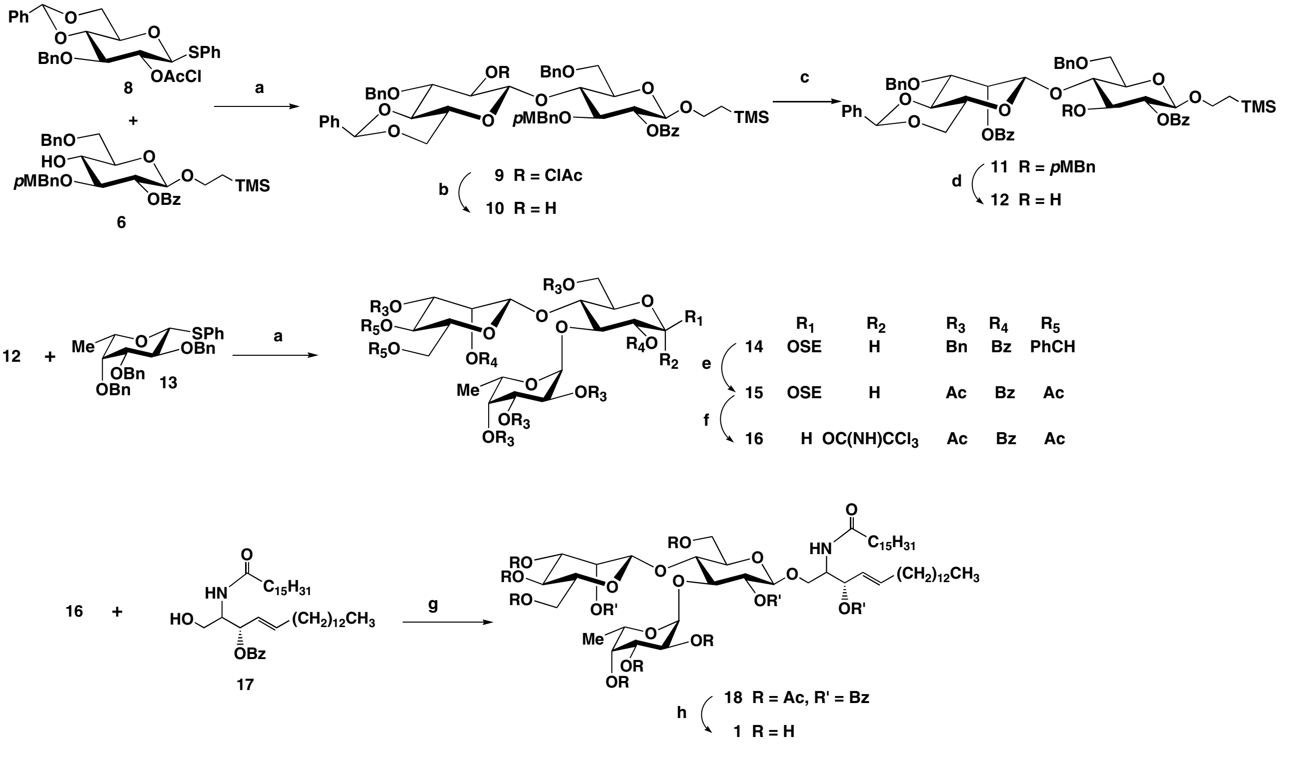


Scheme 1. Reagents: (a) (i) *n*-Bu_2SnO, benzene; (ii) *n*-Bu_4NBr, *p*-MBnCl, toluene; (b) BzCl, pyridine, 71% two steps; (c) $NaBH_3CN$, HCl/Et_2O, THF, 72%; (d) (i) *n*-Bu_2SnO, benzene; (ii) *n*-Bu_4NBr, BnBr, toluene; (e) ClAcCl, CH_2Cl_2/pyridine, 81% two steps.

removal of the chloroacetyl group in **9** with $NaHCO_3$ gave **10**, a disaccharide containing a β-D-glucopyranosyl residue with the C2′ hydroxyl group unsubstituted. Compound **10** was converted into the triflate by treatment with trifluoromethanesulfonic anhydride in the presence of pyridine at 0 °C. The triflate was then subjected to a nucleophilic substitution reaction with tetrabutylammonium benzoate, which inverted the C2′ stereocenter converting the β-D-glucopyranosyl moiety to a β-D-mannopyranosyl residue (**11**) in good overall yield from **10** (80%). The anomeric hydrogen atom of the mannopyranosyl unit appeared in the NMR spectrum as a signal at δ 4.79 (s, H-1′). The β-D configuration of the glycosidic bond was indicated by the $^1J_{C1,H1}$ value of 157.3 Hz (C-1′, 99.4 ppm) in the ^{13}C NMR spectrum.[18] Removal of the 3′-*O*-*p*MBn group from **11** by DDQ gave the disaccharide acceptor **12**. Glycosylation of **12** with known fucopyranosyl donor **13**[19] in the presence of NIS, TfOH and 4 Å molecular sieves in dichloromethane at −60 °C gave the desired trisaccharide **14** (99%). The stereochemistry of the introduced fucopyranosyl residue was evident by ^1H NMR spectroscopy (H-1″, 5.37 ppm, $J = 3.7$ Hz). Removal of the benzylidene and benzyl group from **14** by catalytic hydrogenolysis over 10% Pd/C in THF/CH_3OH/AcOH (3:3:1) and subsequent acetylation gave **15**. Selective removal of the 2-(trimethylsilyl)ethyl (SE) group with trifluoroacetic acid in dichloromethane, and treatment[20] with trichloroacetonitrile in the presence of DBU gave the corresponding α-trichloroacetimidate **16**. Glycosylation of (2*S*,3*R*,4*E*)-3-*O*-benzoyl-2-hexadecanamido-4-octadecene-1,3-diol **17**[6] with **16** was carried out in the presence of trimethylsilyl trifluoromethanesulfonate (TMSOTf) and 4 Å molecular sieves to afford the desired β-glycoside **18** in 35% yield. Finally, removal of acyl groups in **18** under Zemplen conditions and column chromatography on Sephadex LH-20 furnished a target glycolipid **1** (Scheme 2). The structure and purity of **1** was demonstrated by ^1H NMR spectroscopy and high-resolution fast-atom-bombardment mass spectrometry.

2.3. Syntheses of multivalent glycoconjugates

We planned to use glycosyl donor **16** in the syntheses of the multivalent glycoconjugates. Elongation of the glycocluster was done using three iterative reactions: amide bond formation, deprotection of the *tert*-butoxycarbonyl (Boc) group, and deprotection of the trichloroethyl ester (Tce) group. The required building block **24** was prepared as follows. Coupling of trisaccharide imidate **16** with the spacer **19**, which was obtained from hexanolamine, in the presence of TMSOTf gave compound **20** in quantitative yield. Selective removal of the Troc group from **20** by zinc metal and acetic acid gave the primary amine **21** also in quantitative yield. Compound **21** was condensed in the presence of diethyl



Scheme 2. Reagents: (a) NIS, TfOH, 4 Å molecular sieves, CH_2Cl_2 **9**: 57%, **14**: 99%; (b) $NaHCO_3$, THF, 76%; (c) (i) Tf_2O, CH_2Cl_2/pyridine; (ii) *n*-Bu_4NBz, DMF, 80%; (d) DDQ, $CHCl_3/H_2O$ (19:1) 78%; (ii) *n*-Bu_4NBr, BnBr, toluene; (e) (i) H_2, Pd/C, CH_3OH/AcOH; (ii) Ac_2O/pyridine, 60%; (f) (i) TFA, CH_2Cl_2; (ii) CCl_3CN, DBU, CH_2Cl_2, 98%; (g) TMSOTf, 4 Å molecular sieves, CH_2Cl_2 35%; (h) $NaOCH_3$, 1,4-dioxane/CH_3OH, 94%.

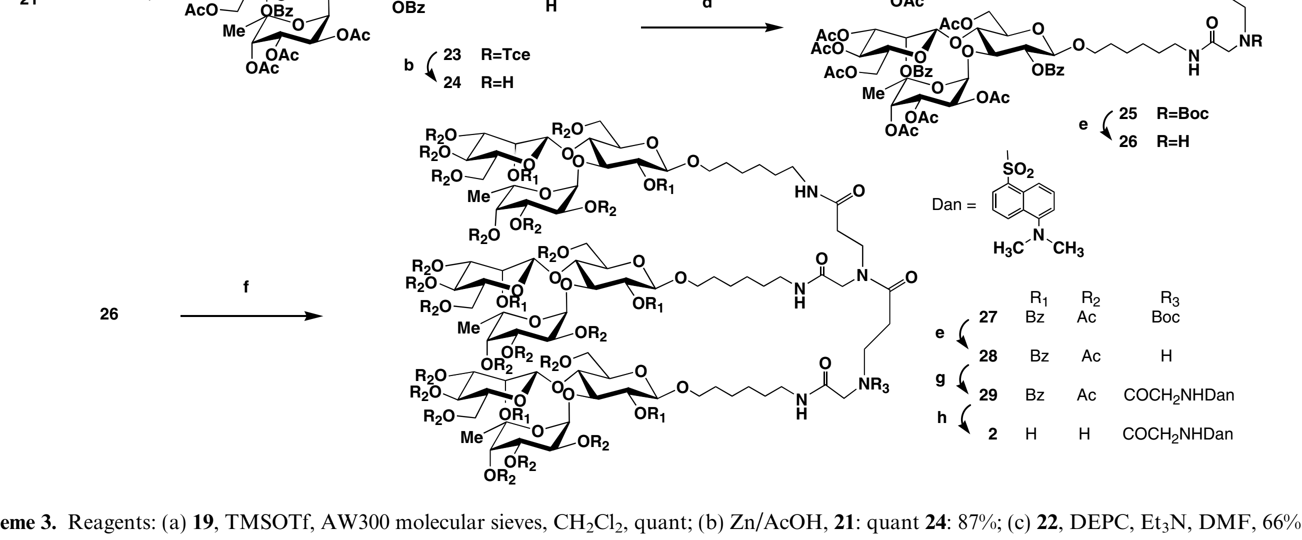
phosphorocyanidate (DEPC) in dry DMF with β-alanine derivative **22**, which was prepared according to a previous paper,[13] to give **23** in 66% yield. Subsequent removal of the Tce group with zinc metal and acetic acid afforded an 87% yield of **24**, which has a free carboxylic acid moiety. Coupling of **24** with **21** gave the dimer **25** in 71% yield. The Boc group of **25** was removed with 50% TFA affording **26** (86% yield), which was subsequently subjected to the next cycle for the elongation to give the desired trimer glycocluster derivative **27** (79%). Dansyl glycine was introduced into the trimer **28** in the presence of DEPC to give compound **29** in 85% yield. Finally, complete removal of the acyl groups provided the fluorescently labeled glycocluster **2** in 91% yield (Scheme 3). Furthermore, coupling of **28** with **24** in a subsequent cycle gave the desired tetramer derivative **30** in 83% yield, and following the cleavage of the Boc group (56% yield), the resulting amine was coupled with dansyl glycine as described for **29** to give compound **32** in 94% yield. Complete removal of the acyl groups and esters afforded **3** in 91% yield (Scheme 4). The structure and purity of **2** and **3** were supported by ^{1}H and ^{13}C NMR as well as mass spectrometry data.

In conclusion, the synthesis of oligosaccharides containing the β-D-Man*p*-(1→4)-Glc*p* structural motifs has been carried out. In addition, an efficient synthetic strategy was developed to obtain new multivalent glycoconjugates. This method should be of use in the preparation of a number of other such species. The results of the biological testing of these compounds will be reported in detail elsewhere.

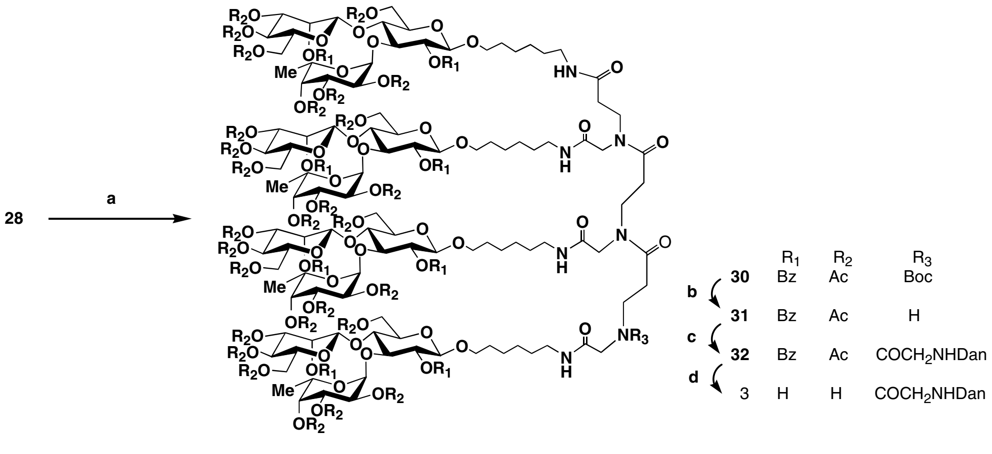
3. Experimental

3.1. General methods

Optical rotations were measured with a Jasco digital polarimeter. ^{1}H NMR and ^{13}C NMR spectra were recorded with a JMN A500 FT NMR spectrometer with $(CH_3)_4Si$ as the internal standard for solutions in $CDCl_3$. MALDI-TOF mass spectra (MALDIMS) were recorded on a Perseptive Voyager RP mass spectrometer. High-resolution mass spectra were recorded on a JEOL JMS-700 under FAB conditions (FABMS). TLC was performed on Silica Gel 60 F_{254} (E. Merck) with detection by quenching of UV fluorescence and by charring with 10% H_2SO_4. Column chromatography was carried out on Silica Gel 60 (E. Merck). 2-(Trimethylsilyl)ethyl 4,6-*O*-benzylidene-β-D-glucopyranoside (**4**),[15] phenyl 4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside (**3**),[16] phenyl 2,3,4-tri-*O*-benzyl-1-thio-β-L-fucopyranoside (**13**)[19] and (2*S*,3*R*,4*E*)-3-*O*-benzoyl-2-hexadecanamido-4-octadecene-1,3-diol (**17**)[6] were prepared as reported in the literature.



Scheme 3. Reagents: (a) **19**, TMSOTf, AW300 molecular sieves, CH_2Cl_2, quant; (b) Zn/AcOH, **21**: quant **24**: 87%; (c) **22**, DEPC, Et_3N, DMF, 66%; (d) **21**, DEPC, Et_3N, DMF, 71%; (e) 50% TFA, **26**: 86%, **28**: 73%; (f) **24**, DEPC, Et_3N, DMF, 79%; (g) dansyl glycine, DEPC, Et_3N, DMF, 85%; (h) $NaOCH_3$, 1,4-dioxane/CH_3OH, 91%.



Scheme 4. Reagents: (a) **24**, DEPC, Et_3N, DMF, 83%; (b) 50% TFA, 56%; (c) dansyl glycine, DEPC, Et_3N, DMF, 94%; (d) $NaOCH_3$, 1,4-dioxane/CH_3OH, 91%.

3.2. 2-(Trimethylsilyl)ethyl 2-*O*-benzoyl-4,6-*O*-benzylidene-3-*O*-*p*-methoxybenzyl-1-thio-β-D-glucopyranoside (5a) and 2-(trimethylsilyl)ethyl 3-*O*-benzoyl-4,6-*O*-benzylidene-2-*O*-*p*-methoxybenzyl-β-D-glucopyranoside (5b)

A mixture of 2-(trimethylsilyl)ethyl 4,6-*O*-benzylidene-β-D-glucopyranoside (**4**) (2.9 g, 7.88 mmol), *n*-Bu_2SnO (2.2 g, 8.83 mmol) and 80 mL of dry benzene was stirred at reflux for 5 h. The benzene was distilled off and the stannylidene derivative was redissolved in toluene (20 mL), and *n*-Bu_4NBr (2.5 g, 7.76 mmol) and *p*-methoxybenzyl chloride (1.6 mL, 11.8 mmol) were added at 60 °C. After stirring the reaction mixture for 5 h, the solution was concentrated. Purification of the residue by column chromatography (10:1, toluene/EtOAc) on silica gel gave a mixture of 2-(trimethylsilyl)ethyl 4,6-*O*-benzylidene-3-*O*-*p*-methoxybenzyl-β-D-glucopyranoside and 2-(trimethylsilyl)ethyl 4,6-*O*-benzylidene-2-*O*-*p*-methoxybenzyl-β-D-glucopyranoside (3.1 g, 81%); MALDIMS *m*/*z* calcd for $[C_{26}H_{36}O_7Si+Na]^+$: 511.2. Found: 511.3. To a solution of these compounds (3.1 g, 6.34 mmol) in pyridine (20 mL) was added benzoyl chloride (1.5 mL, 12.9 mmol), and the reaction mixture was stirred for 4 h at rt. Toluene was added and the solution was evaporated, the residue was extracted with $CHCl_3$, washed with 5% HCl, aq $NaHCO_3$, and H_2O, dried ($MgSO_4$), and concentrated. The product was purified by silica gel column chromatography using 6:1 hexane/EtOAc as eluent to give the mixture of **5a** and **5b** (3.2 g, 85%): MALDIMS *m*/*z* calcd for $[C_{33}H_{40}O_8Si+Na]^+$: 615.3. Found: 615.5.

3.3. 2-(Trimethylsilyl)ethyl 2-*O*-benzoyl-6-*O*-benzyl-3-*O*-*p*-methoxybenzyl-β-D-glucopyranoside (6a)

To a solution of compounds **5a** and **5b** (2.9 g, 4.89 mmol) and sodium cyanoborohydride (2.4 g, 38.2 mmol) in dry THF (50 mL) was added powdered 3 Å molecular sieves (3 g), and the mixture was stirred for 2 h at rt, then cooled to 0 °C. Hydrogen chloride in Et_2O was added until the solution was acidic (pH paper, gas evolution). After 1 h, the reaction mixture was poured into ice H_2O and extracted with $CHCl_3$. The extract was washed sequentially with aq $NaHCO_3$ and H_2O, dried (Na_2SO_4), and concentrated. The product was purified by silica gel column chromatography using 3:1 hexane/EtOAc as eluent to give **6a** (1.24 g, 45%) and **6b** (851 mg, 29%): compound **6a**: ^1H NMR ($CDCl_3$): δ 8.00–6.64 (m, 14H, 3*Ph*), 5.18 (dd, 1H, $J_{1,2} = 7.9$ Hz, $J_{2,3} = 9.2$ Hz, H-2), 4.62–4.50 (m, 4H, $2PhCH_2$), 4.57 (d, 1H, H-1), 3.98 (dt, 1H, CH_2CH_2Si), 3.79–3.71 (m, 3H, H-4, 6a, 6b), 3.67 (s, 3H, OCH_3), 3.61 (dd, 1H, H-3), 3.53–3.46 (m, 2H, H-5, CH_2CH_2Si), 2.81 (d, 1H, O*H*), 0.87–0.74 (m, 2H, CH_2CH_2Si), −0.14 (s, 9H, $Si(CH_3)_3$); ^{13}C NMR ($CDCl_3$): δ 165.1, 159.2, 137.8, 132.9, 130.1, 129.9, 129.7, 129.6, 128.4, 127.8, 127.7, 113.7, 100.6 (C-1), 81.9 (C-3), 74.2 (C-5), 73.9 ($PhCH_2$), 73.7 ($PhCH_2$), 73.5 (C-2), 72.2 (C-4), 70.4 (C-6), 67.2 (CH_2), 55.1 (OCH_3), 17.9 (CH_2CH_2Si), −1.6 ($Si(CH_3)_3$); MALDIMS *m*/*z* calcd for $[C_{33}H_{42}O_8Si+Na]^+$: 617.3. Found: 617.4. Compound **6b**: ^1H NMR ($CDCl_3$): δ 7.96–6.58 (m, 14H, 3*Ph*), 5.18 (t, 1H, $J_{2,3\,3,4} = 9.2$ Hz, H-3), 4.72–4.53 (m, 4H, $2PhCH_2$), 4.48 (d, 1H, $J_{1,2} = 7.3$ Hz, H-1), 4.00 (dt, 1H, CH_2CH_2Si), 3.78–3.59 (m, 4H, H-4, 6a, 6b, CH_2), 3.68 (s, 3H, OCH_3), 3.49 (dt, 1H, H-5), 3.44 (dd, 1H, H-2), 3.06 (d, 1H, O*H*), 0.71–0.60 (m, 2H, CH_2CH_2Si), −0.17 (s, 9H, $Si(CH_3)_3$); ^{13}C NMR ($CDCl_3$): δ 167.1, 159.0, 137.8, 133.1, 130.1, 129.9, 129.8, 129.6, 128.4, 128.2, 127.8, 113.5, 103.1 (C-1), 78.0 (C-3), 77.8 (C-2), 74.3 (C-5), 73.63 ($PhCH_2$), 73.60 ($PhCH_2$), 71.0 (C-4), 70.1 (C-6), 67.6 (CH_2), 55.1 (OCH_3), 18.5 (CH_2CH_2Si), −1.4 ($Si(CH_3)_3$).

3.4. Phenyl 4,6-*O*-benzylidene-3-*O*-benzyl-2-*O*-chloroacetyl-1-thio-β-D-glucopyranoside (8)

A mixture of phenyl 4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside (**7**) (1.0 g, 2.67 mmol), *n*-Bu_2SnO

(731 mg, 2.94 mmol), and 20 mL of dry benzene was stirred at reflux for 5 h. The benzene was distilled off and the stannylidene derivative was redissolved in toluene (10 mL) and then *n*-Bu_4NBr (1.29 g, 4.01 mmol) and benzyl bromide (0.48 mL, 4.04 mmol) were added at 60 °C. After the reaction mixture was stirred for 5 h, the solution was concentrated. Purification of the residue by column chromatography (20:1, toluene/EtOAc) on silica gel gave phenyl 4,6-*O*-benzylidene-3-*O*-benzyl-β-D-glucopyranoside (1.08 g, 84%); MALDIMS *m*/*z* calcd for $[C_{26}H_{26}O_5S+Na]^+$: 473.2. Found: 473.3. To a solution of this compound (1.08 g, 2.25 mmol) in CH_2Cl_2/pyridine (4:1, 10 mL) was added chloroacetyl chloride (0.35 mL) and the mixture was stirred for 2 h at 0 °C. Toluene was added and evaporated, then extracted with $CHCl_3$, washed with 5% HCl, aq $NaHCO_3$, and H_2O, dried ($MgSO_4$), and concentrated. The product was purified by silica gel column chromatography using 20:1 benzene/EtOAc as the eluent to give **8** (1.17 g, 96%): $[\alpha]_D^{24}$ +12.5 (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.49–7.24 (m, 15H, 3*Ph*), 5.57 (s, 1H, PhC*H*), 5.02 (dd, 1H, $J_{1,2} = 8.5$ Hz, $J_{2,3} = 10.3$ Hz, H-2), 4.86, 4.63 (each d, 2H, $PhCH_2$), 4.68 (d, 1H, H-1), 4.39 (dd, 1H, $J_{5,6a} = 10.4$ Hz, $J_{6a,6b} = 4.7$ Hz, H-6a), 3.94, 3.83 (each d, 2H, CH_2Cl), 3.81–3.71 (m, 3H, H-3, 4, 6b), 3.50 (dt, 1H, H-5); ^{13}C NMR ($CDCl_3$): δ 165.7, 137.9, 137.0, 133.0, 131.5, 129.1, 129.0, 128.4, 128.3, 128.0, 127.8, 125.9, 101.2 (PhC*H*), 86.2 (C-1), 81.2 (C-3), 79.4 (C-4), 74.4 ($PhCH_2$), 72.8 (C-2), 70.5 (C-5), 68.4 (C-6), 40.6 (CH_2Cl); MALDIMS *m*/*z* calcd for $[C_{29}H_{30}ClO_6S+Na]^+$: 564.1. Found: 564.0.

3.5. 2-(Trimethylsilyl)ethyl 4,6-*O*-benzylidene-3-*O*-benzyl-2-*O*-chloroacetyl-β-D-glucopranosyl-(1→4)-2-*O*-benzoyl-6-*O*-benzyl-3-*O*-*p*-methoxybenzyl-β-D-glucopyranoside (9)

A solution of compound **6a** (840 mg, 1.41 mmol) and **8** (1.3 g, 2.47 mmol) containing activated 4 Å molecular sieves (1.5 g) in dry CH_2Cl_2 (10 mL) was stirred under an atmosphere of argon for 2 h at rt. After cooling to −40 °C, NIS (828 mg, 3.70 mmol) and TfOH (22 µL, 250 µmol) were successively added and stirring was continued at −40 °C for 30 min before the solution was neutralized with Et_3N. The reaction mixture was filtered, and the filtrate was washed with sodium thiosulfate and H_2O, dried ($MgSO_4$), and concentrated. The product was purified by silica gel column chromatography using 20:1 toluene/EtOAc as the eluant to give **9** (810 mg, 57%). $[\alpha]_D^{24}$ +7.2 (*c* 0.5, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.96–6.63 (m, 24H, 5*Ph*), 5.50 (s, 1H, PhC*H*), 5.16 (t, 1H, $J_{1,2}$, $J_{2,3} = 7.9$ Hz, H-2), 4.98 (t, 1H, $J_{1',2'}$, $J_{2',3'} = 7.9$ Hz, H-2′), 4.88–4.47 (m, 6H, $3PhCH_2$), 4.61 (d, 1H, $J_{1',2'} = 7.9$ Hz, H-1′), 4.47 (d, 1H, H-1), 4.23 (dd, 1H, $J_{5',6'a} = 10.6$ Hz, $J_{6'a,6'b} = 3.7$ Hz, H-6′a), 4.07 (t, 1H, H-4), 3.94 (dt, 1H, CH_2CH_2Si), 3.82, 3.77 (each, d, 2H, CH_2Cl), 3.75–3.39 (m, 11H, H-3, H-6a, H-6b, H-6′b, 3′, 4′, 5′, OCH_3, CH_2CH_2Si), 3.18 (dt, 1H, H-5), 0.90–0.80 (m, 2H, CH_2CH_2Si), −0.09 (s, 9H, $Si(CH_3)_3$); ^{13}C NMR ($CDCl_3$): δ 165.8, 165.0, 138.1, 137.9, 137.1, 132.8, 130.4, 130.2, 129.8, 129.4, 129.1, 128.5, 128.4, 128.3, 128.18, 128.15, 128.0, 127.9, 127.8, 126.0, 113.5, 101.3 (PhC*H*), 100.6 (C-1′), 100.1 (C-1), 81.7, 80.0, 78.2, 76.6, 75.1, 75.1, 75.0, 74.2, 74.0. 73.7, 73.3, 68.6, 67.8, 67.1, 66.0, 55.1 (OCH_3), 40.5 (CH_2Cl), 17.9 (CH_2CH_2Si), −1.5 ($Si(CH_3)_3$); MALDIMS *m*/*z* calcd for $[C_{55}H_{64}ClO_{14}Si+Na]^+$: 1034.1. Found: 1034.0.

3.6. 2-(Trimethylsilyl)ethyl 4,6-*O*-benzylidene-3-*O*-benzyl-β-D-glucopranosyl-(1→4)-2-*O*-benzoyl-6-*O*-benzyl-3-*O*-*p*-methoxybenzoyl-β-D-glucopyranoside (10)

A solution of **9** (980 mg, 0.97 mmol), saturated $NaHCO_3$ in CH_3OH/H_2O (5:1 v/v) solution (48 mL), and THF (12 mL) was stirred for 1 h at 50 °C. The solution was evaporated, then extracted with $CHCl_3$, washed with H_2O, dried ($MgSO_4$), and concentrated. The product was purified by silica gel column chromatography using 60:1 toluene/EtOAc as the eluent to give **10** (700 mg, 77%): $[\alpha]_D^{24}$ +29.1 (*c* 2.0, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 7.98–6.63 (m, 24H, 5*Ph*), 5.57 (s, 1H, PhC*H*), 5.22 (t, 1H, $J_{1,2}$, $J_{2,3} = 9.2$ Hz, H-2), 4.94–4.50 (m, 6H, $3PhCH_2$), 4.65 (d, 1H, $J_{1',2'} = 7.3$ Hz, H-1′), 4.51 (d, 1H, H-1), 4.16–4.11 (m, 2H, H-4, 6a), 4.00 (dd, 1H, $J_{5',6'a} = 10.6$ Hz, $J_{6'a,6'b} = 3.7$ Hz, H-6′a), 3.94 (dt, 1H, CH_2CH_2Si), 3.82 (dd, 1H, $J_{5',6'b} = 1.8$ Hz, H-6′b), 3.77 (dd, 1H, H-3), 3.66 (s, 3H, OCH_3), 3.61–3.49 (m, 6H, H-6b, 2′, 3′, 4′, 5′, CH_2CH_2Si), 3.19 (dt, 1H, H-5), 0.91–0.80 (m, 2H, CH_2CH_2Si), −0.09 (s, 9H, $Si(CH_3)_3$); ^{13}C NMR ($CDCl_3$): δ 103.4 (C-1′), 101.1 (PhC*H*) 100.1 (C-1), 81.2 (C-3), 81.1 (C-3′), 80.3 (C-4′), 77.4 (C-5), 75.1 (C-2′), 74.7 (C-5 $PhCH_2$), 74.5 ($PhCH_2$), 73.5 (C-2), 68.6 (C-6), 68.2 (C-6′), 67.0 (CH_2), 66.2 (C-5), 55.0 (OCH_3), 17.7 (CH_2CH_2Si), −1.4 ($Si(CH_3)_3$); MALDIMS *m*/*z* calcd for $[C_{53}H_{62}O_{13}Si+Na]^+$: 957.4. Found: 957.2.

3.7. 2-(Trimethylsilyl)ethyl 4,6-*O*-benzylidene-2-*O*-benzoyl-3-*O*-benzyl-β-D-mannopyranosyl-(1→4)-2-*O*-benzoyl-6-*O*-benzyl-3-*O*-*p*-methoxybenzyl-β-D-glucopyranoside (11)

To a solution of **10** (563 mg, 0.60 mmol) in CH_2Cl_2 (6 mL) and pyridine (3 mL), cooled to −20 °C was added triflic anhydride (610 µL, 3.60 mmol), and the reaction mixture was stirred for 1 h at −20 °C and then for 1 h at 0 °C. Toluene was added and the solution was evaporated, then extracted with $CHCl_3$, washed with 5% HCl, aq $NaHCO_3$, and H_2O, dried ($MgSO_4$), and concentrated. The resulting residue was dissolved in DMF (6 mL) and *n*-Bu_4NOBz (1.75 g, 4.81 mmol), was added and the mixture was stirred for 1.5 h at rt, then for 1 h at 100 °C. Toluene was added and the solution was concentrated. The residue was purified by silica gel column chromatography using 10:1 toluene/EtOAc as the eluent to give **11** (501 mg 80%): $[\alpha]_D^{25}$ −15.3 (*c* 1.0 $CHCl_3$); ^1H NMR ($CDCl_3$): δ 8.11–6.44 (m, 29H, 6*Ph*), 5.70 (d, 1H, $J_{2',3'} = 3.7$ Hz, H-2′), 5.60 (s, 1H, PhC*H*), 5.12 (dd, 1H, $J_{1,2} = 7.9$ Hz, $J_{2,3} = 9.2$ Hz, H-2), 4.79 (s, 1H, H-1′), 4.75–4.38 (m, 6H, 3PhCH_2), 4.42 (d, 1H, H-1), 4.30 (dd, 1H, $J_{5',6'a} = 10.4$ Hz, $J_{6'a,6'b} = 4.3$ Hz, H-6′a), 4.14 (t, 1H, $J_{3,4\,4,5} = 9.2$ Hz, H-4), 4.02 (t, 1H, $J_{3',4'4',5'} = 9.2$Hz, H-4′), 3.92 (dt, 1H, OCH_2CH_2Si), 3.82–3.75 (m, 3H, H-6a, H-6b, H-6′b), 3.63 (s, 3H, CH_3O), 3.56 (t, 1H, H-3), 3.55 (t, 1H, H-3′), 3.49–3.42 (m, 2H, H-5, OCH_2CH_2Si), 3.20 (dt, 1H, H-5′), 0.87–0.75 (m, 2H, OCH_2CH_2Si), −0.12 (s, 9H, Si(CH_3)$_3$); ^{13}C NMR ($CDCl_3$): δ 165.8, 164.9, 158.7, 137.9, 137.8, 137.4, 133.3, 132.7, 130.5, 130.2, 129.9, 129.8, 129.7, 129.4, 129.0, 128.9, 128.5, 128.4, 128.2, 127.6, 127.4, 126.1, 125.4, 113.2, 101.6 (Ph*C*H), 100.6 (C-1, $J_{C1,H1} =$ 159.3Hz), 99.4 (C-1′, $J_{C1,H1} = 157.3$ Hz), 79.9 (C-3), 78.3 (C-4), 78.0 (C-4′), 75.8 (C-3′), 75.2 (Ph*C*H_2), 74.5 (C-5), 74.0 (Ph*C*H_2), 73.6 (Ph*C*H_2), 73.1 (C-2), 71.5 (Ph*C*H_2), 69.7 (C-2′), 68.7 (C-6), 68.5 (C-6′), 67.03 (C-5′), 66.98 (O*C*H_2CH_2Si), 55.0, 17.8, −1.5; MALDIMS *m*/*z* calcd for $[C_{60}H_{66}O_{14}Si{+}Na]^+$: 1061.4. Found: 1061.2.

3.8. 2-(Trimethylsilyl)ethyl 4,6-*O*-benzylidene-2-*O*-benzoyl-3-*O*-benzyl-β-D-mannopyranosyl-(1→4)-2-*O*-benzoyl-6-*O*-benzyl-β-D-glucopyranoside (12)

To a solution of **11** (177 mg, 0.45 mmol) in CH_2Cl_2 (19 mL) and H_2O (1 mL) was added DDQ (153 mg, 0.67 mmol), and the mixture was stirred for 10 h at rt. The reaction mixture was filtered, and the filtrate was washed with H_2O, dried ($MgSO_4$), and concentrated. The residue was purified by silica gel column chromatography using 8:1 toluene/EtOAc as the eluent to give **12** (323 mg, 78%): $[\alpha]_D^{23}$ −55.7 (*c* 1.6, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 8.07–7.15 (m, 25H, 5*Ph*,), 5.60 (s, 1H, PhC*H*), 5.58 (d, 1H, $J_{2',3'} = 3.7$ Hz, H-2′), 5.14 (dd, 1H, $J_{1,2} = 8.6$ Hz, $J_{2,3} = 9.8$ Hz, H-2), 4.79–4.47 (m, 4H, 2PhCH_2), 4.54 (s, 1H, H-1′), 4.49 (d, 1H, H-1), 4.35 (dd, 1H, $J_{5',6'a} = 10.3$ Hz, $J_{6'a,6'b} = 4.6$ Hz, H-6′a), 4.03 (t, 1H, $J_{3',4'4',5'} = 9.8$ Hz, H-4′), 3.96 (m, 1H, OCH_2CH_2Si), 3.89–3.72 (m, 6H, H-3, 4, H-6a, H-6b, H-6′b, OH), 3.60 (dd, 1H, H-3′), 3.49 (dt, 1H, OCH_2CH_2Si), 3.43 (dt, 1H, H-5), 3.37 (dt, 1H, H-5′), 0.91–0.78 (m, 2H, OCH_2CH_2Si), −0.10 (s, 9H, Si(CH_3)$_3$); ^{13}C NMR ($CDCl_3$): δ 165.8, 165.3, 138.1, 137.7, 137.1, 133.2, 132.9, 130.1, 129.91, 129.86, 129.0, 128.5, 128.44, 128.36, 128.2, 128.1, 128.03, 127.95, 127.7, 127.5, 126.1, 101.6 (Ph*C*H), 100.5 (C-1), 100.3 (C-1′), 80.8 (C-4), 78.0 (C-4′), 75.5 (C-3′), 73.7 (C-5), 73.50 (2Ph*C*H_2), 73.45 (C-2), 71.8 (Ph*C*H_2), 69.2 (C-2′), 68.2 (C-3), 68.1 (C-5′), 67.1 (C-6, C-6′), 67.0 (O*C*H_2CH_2Si), 17.9, −1.5; MALDIMS *m*/*z* calcd for $[C_{52}H_{58}O_{13}Si{+}Na]^+$: 941.4. Found: 941.0.

3.9. 2-(Trimethylsilyl)ethyl 4,6-*O*-benzylidene-2-*O*-benzoyl-3-*O*-benzyl-β-D-mannopyranosyl-(1→4)-[2,3,4-tri-*O*-benzyl-α-L-fucopyranosyl-(1→3)]-2-*O*-benzoyl-6-*O*-benzyl-β-D-glucopyranoside (14)

To a solution of **12** (221 mg, 0.24 mmol) and **13** (381 mg, 0.72 mmol) in dry CH_2Cl_2 (3 mL) was added powdered 4 Å molecular sieves (1 g), and the mixture was stirred for 2 h at rt, then cooled to −60 °C. NIS (241 mg, 1.08 mmol) and TfOH (6.0 μL, 72 μmol) were added to the mixture, which was stirred for 10 min at −60 °C, then neutralized with Et_3N. The solids were filtered and washed with $CHCl_3$. The combined filtrate and washings were successively washed with aq $Na_2S_2O_3$ and H_2O, dried ($MgSO_4$), and concentrated. The product was purified by silica gel column chromatography using 3:1 hexane/EtOAc as eluent to give **14** (317 mg, 99%): $[\alpha]_D^{24}$ −67.2 (*c* 1.6, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 8.06–7.09 (m, 40H, 8*Ph*), 5.70 (d, 1H, $J_{2',3'} = 3.1$ Hz, H-2′), 5.52 (s, 1H, PhC*H*), 5.40 (t, 1H, $J_{1,2\,2,3} = 7.9$ Hz, H-2), 5.37 (d, $J_{1'',2''} = 3.7$ Hz, H-1″), 4.89 (s, 1H, H-1′), 4.88–4.17 (m, 14H, H-3, 4, H-6′a, H-5″, 5PhCH_2), 4.40 (d, 1H, H-1), 3.97–3.78 (m, 5H, H-6a, H-6a′, H-2″, H-3″, H-4″, OCH_2CH_2Si), 3.62 (t, 1H, H-4′), 3.51–3.43 (m, 4H, H-5, H-6′b, H-3′, OCH_2CH_2Si), 3.12 (dt, 1H, H-5′), 0.80–0.73 (m, 2H, OCH_2CH_2Si), 0.72 (d, 3H, H-6″), −0.10 (s, 9H, Si(CH_3)$_3$); ^{13}C NMR ($CDCl_3$): δ 166.0, 164.8, 139.2, 138.7, 138.1, 137.8, 137.7, 137.2, 133.3, 133.03, 129.94, 129.8, 129.0, 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.7, 127.4, 127.2, 126.8, 126.1, 125.3, 101.4, 100.54 (C-1′), 100.46 (C-1), 95.5 (C-1″), 78.8, 78.6, 78.4, 78.3, 76.3, 75.7, 75.2, 74.9, 74.8, 73.7, 73.5, 73.0, 72.3, 71.6, 70.2, 68.9, 68.6, 67.1, 67.0, 66.1, 17.8, 16.5, −1.6; MALDIMS *m*/*z* calcd for $[C_{79}H_{86}O_{17}Si{+}Na]^+$: 1358.4. Found: 1358.6.

3.10. 2-(Trimethylsilyl)ethyl 3,4,6-tri-*O*-acetyl-2-*O*-benzoyl-β-D-mannopyranosyl-(1→4)-[2,3,4-tri-*O*-acetyl-α-L-fucopyranosyl-(1→3)]-2-*O*-benzoyl-6-*O*-acetyl-β-D-glucopyranoside (15)

A solution of **14** (386 mg, 0.29 mmol) in THF (3.0 mL), CH_3OH (3.0 mL), and AcOH (1.0 mL) was hydrogenolysed in the presence of 10% Pd/C (400 mg) for 3 h at rt, then filtered and concentrated. The residue was acetylated with acetic anhydride (4 mL) in pyridine (6 mL). The reaction mixture was poured into ice H_2O and extracted with $CHCl_3$. The extract was washed sequentially with 5% HCl, aq $NaHCO_3$, and H_2O, dried ($MgSO_4$), and concentrated. The residue was purified by silica gel column chromatography using 6:1 toluene/acetone as eluent to give **15** (315 mg, quant): $[\alpha]_D^{24}$ −91.9 (*c* 1.5, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 5.28 (d, $J_{1'',2''} = 3.1$ Hz, H-1″), 4.90 (s, 1H, H-1′), 4.45 (d, 1H, $J_{1,2} = 7.9$ Hz, H-1); ^{13}C NMR ($CDCl_3$): δ 100.7 (C-1′), 100.1 (C-1), 95.2 (C-1″); MALDIMS m/z calcd for $[C_{51}H_{66}O_{24}Si+Na]^+$: 1114.1. Found: 1114.4.

3.11. 3,4,6-Tri-*O*-acetyl-2-*O*-benzoyl-β-D-mannopyranosyl-(1→4)-[2,3,4-tri-*O*-acetyl-α-L-fucopyranosyl-(1→3)]-2-*O*-benzoyl-6-*O*-acetyl-α-D-glucopyranosyl trichloroacetimidate (16)

To a solution of **15** (320 mg, 0.29 mmol) in CH_2Cl_2 (2.0 mL), cooled to 0 °C was added CF_3CO_2H (4 mL), and the mixture was stirred for 2.5 h at rt and concentrated. EtOAc and toluene (1:2) were added and evaporated to give the reducing sugar. To a solution of the residue in CH_2Cl_2 (1.0 mL) cooled at 0 °C were added Cl_3CCN (290 µL, 2.9 mmol) and DBU (43 µL, 0.29 mmol). The reaction mixture was stirred for 2 h at 0 °C. After completion of the reaction, the mixture was concentrated. Column chromatography of the residue on silica gel (1:2, hexane/EtOAc) gave **16** (285 mg, 86%): $[\alpha]_D^{25}$ −39.6 (c 1.6, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 6.50 (d, 1H, $J_{1,2} = 3.7$ Hz, H-1), 5.43 (d, $J_{1'',2''} = 3.1$ Hz, H-1″), 4.92 (s, 1H, H-1′); ^{13}C NMR ($CDCl_3$): δ 100.6 (C-1′), 95.9 (C-1″), 92.9 (C-1).

3.12. 3,4,6-Tri-*O*-acetyl-2-*O*-benzoyl-β-D-mannopyranosyl-(1→4)-[2,3,4-tri-*O*-acetyl-α-L-fucopyranosyl-(1→3)]-2-*O*-benzoyl-6-*O*-acetyl-β-D-glucopyranosyl-(1→1)-(2*S*,3*R*,4*E*)-3-*O*-benzoyl-2-hexadecanamido-4-octadecene-1,3-diol (18)

To a solution of **16** (63 mg, 55 µmol) and (2*S*,3*R*,4*E*)-3-*O*-benzoyl-2-hexadecanamido-4-octadecene-1,3-diol **17** (53 mg, 83 µmol) in dry CH_2Cl_2 (1.0 mL) was added 4 Å molecular sieves (350 mg), and the mixture was stirred for 2 h at rt, then cooled to 0 °C. TMSOTf (8 µL, 44 µmol) was added, and the mixture was stirred for 24 h at 0 °C, and then neutralized with Et_3N. The solids were filtrated and washed with $CHCl_3$. The combined filtrate and washings were successively washed with H_2O, dried ($MgSO_4$), and concentrated. The product was purified by silica gel column chromatography using 3:1 toluene/EtOAc as eluent to give **18** (31 mg, 35%): $[\alpha]_D^{25}$ −64.4 (c 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 5.28 (d, $J_{1'',2''} = 3.1$ Hz, H-1″), 4.83 (s, 1H, H-1′), 4.40 (d, 1H, $J_{1,2} = 7.9$ Hz, H-1); ^{13}C NMR ($CDCl_3$): δ 100.7 (C-1′), 100.4 (C-1), 95.3 (C-1″); MALDIMS m/z calcd for $[C_{87}H_{123}NO_{27}+Na]^+$: 1636.8. Found: 1636.5.

3.13. β-D-Mannopyranosyl-(1→4)-[α-L-fucopyranosyl-(1→3)]-β-D-glucopyranosyl-(1→1)-(2*S*,3*R*,4*E*)-2-hexadecanamido-4-octadecene-1,3-diol (1)

To a solution of **18** (31 mg, 19.2 µmol) in CH_3OH (1.0 mL) and 1,4-dioxane (1.0 mL) was added $NaOCH_3$ (20 mg) at rt and the mixture was stirred for 24 h, then neutralized with Amberlite IR 120[H^+]. The mixture was filtered and concentrated. The product was purified by Sephadex LH-20 column chromatography (1:1, $CHCl_3/CH_3OH$) to give **1** (18 mg, 94%): $[\alpha]_D^{24}$ −8.5 (c 0.1, 1:1 $CHCl_3/CH_3OH$); ^1H NMR (DMSO-d_6/D_2O, 19:1): δ 5.24 (d, 1H, $J_{1'',2''} = 4.3$ Hz, H-1″), 4.65 (s, 1H, H-1′), 4.18 (d, 1H, $J_{1,2} = 7.3$ Hz, H-1); MALDIMS m/z calcd for $[C_{52}H_{97}NO_{17}+Na]^+$: 1030.7. Found: 1030.2. FABMS m/z calcd for $[C_{52}H_{97}NO_{17}+Na]^+$: 1030.6654. Found: 1030.6632.

3.14. *N*-(2,2,2-Trichloroethoxycarbonyl)hexanolamine (19)

To a solution of 2,2,2-trichloroethylchloroformate (4.7 mL, 0.03 mol) in 5 mL of dioxane was added at 0 °C a mixture of hexanolamine (5 g, 0.04 mol) and MgO (3 g) in dioxane/H_2O (1:1, 50 mL). The mixture was stirred for 16 h at rt and then EtOAc was added, the solids were filtered and washed with 5% HCl, aq $NaHCO_3$, and H_2O, dried ($MgSO_4$), and concentrated. The product was purified by silica gel column chromatography (200:1, $CHCl_3/CH_3OH$) to give **19** (8 g, 64%): ^1H NMR (500 MHz, $CDCl_3$): δ 5.03 (1H, s, NH), 4.72 (2H, s, CH_2CCl$_3$), 3.65 (2H, t, CH_2OH), 3.24 (2H, dd, NHCH_2), 1.61–1.36 (8H, m, 4CH_2); MALDIMS: m/z calcd for $[C_9H_{16}Cl_3NO_3+Na]^+$: 314.0. Found: 314.3.

3.15. 6-*N*-(2,2,2-Trichloroethoxycarbonyl)aminohexyl 3,4,6-tri-*O*-acetyl-2-*O*-benzoyl-β-D-mannopyranosyl-(1→4)-[2,3,4-tri-*O*-acetyl-α-L-fucopyranosyl-(1→3)-]2-*O*-benzoyl-6-*O*-acetyl-β-D-glucopyranoside (20)

To a solution of **16** (285 mg, 0.25 mmol) and **19** (95 mg, 0.33 mmol) in dry CH_2Cl_2 (2.0 mL) was added AW300 molecular sieves (500 mg), and the mixture was stirred for 2 h at rt, then cooled to 0 °C. TMSOTf (5.8 µL, 25.0 µmol) was added and the mixture was stirred for 4 h at 0 °C, then neutralized with Et_3N. The solids were filtrated and washed with $CHCl_3$. The combined filtrate and washings were successively washed with H_2O, dried ($MgSO_4$), and concentrated. The product was purified by silica gel column chromatography using 5:1 toluene/acetone as eluent to give **20** (316 mg, quant): $[\alpha]_D^{25}$ −86.7 (c 1.4, $CHCl_3$); ^1H NMR ($CDCl_3$): δ 8.09–7.14 (m, 10H, 2Ph), 5.78 (d, 1H, $J_{2',3'} = 3.1$ Hz, H-2′), 5.51 (t, 1H, $J_{3',4'}$, $J_{4',5'} = 10.4$ Hz, H-4′), 5.37 (dd, 1H, $J_{2'',3''} = 3.1$ Hz, $J_{3'',4''} = 11.0$ Hz, H-3″), 5.30 (d, 1H, $J_{1'',2''} = 4.3$ Hz, H-1″), 5.26 (t, 1H, $J_{1,2\,2,3} = 8.6$ Hz, H-2), 5.23 (d, 1H, H-4″), 5.15 (dd, 1H, H-3′), 4.94 (dd, 1H, H-4″), 4.90 (s, 1H, H-1′), 4.86 (dd, 1H, H-5″), 4.78 (dd, 1H, $J_{5',6'a} = 3.1$ Hz, $J_{6'a,6'b} = 13.5$ Hz, H-6′a), 4.62 (s, 2H, CH_2CCl$_3$), 4.59 (dd, 1H, $J_{5,6a} = 2.5$ Hz, $J_{6a,6b} = 12.2$ Hz, H-6a), 4.41 (dd, 1H, H-6′b), 4.40 (d, 1H, H-1), 4.28 (dd, 1H, H-6b), 4.11 (t, 1H, $J_{3,4\,4,5} = 9.1$ Hz, H-4), 4.01 (t, 1H, H-3), 3.80 (dt, 1H, OC*H*$_2$CH$_2$), 3.73 (dt, 1H, H-5′), 3.60 (dt, 1H, H-5), 3.33 (dt, 1H, OCH$_2$C*H*$_2$), 3.00 (dd, 2H, C*H*$_2$NH), 2.22, 2.18, 2.04, 2.03, 2.02, 1.92, 1.91 (each s, 21H, 7Ac), 1.45–1.06 (m, 8H, 4C*H*$_2$), 0.61 (d, 3H, H-6″); ^{13}C NMR (CDCl$_3$): δ 170.4, 170.2, 170.1, 169.8, 169.7, 169.4, 165.8, 154.4, 137.8, 133.5, 129.9, 129.6, 129.4, 129.3 129.0, 128.5, 128.4, 128.2, 125.2, 100.8 (C-1), 100.7 (C-1′), 95.7 (*C*Cl$_3$), 95.2 (C-1″), 79.2 (C-3), 74.6 (C-2), 74.3 (*C*H$_2$CCl$_3$), 73.9 (C-4), 73.2 (C-5′), 73.1 (C-5), 71.5 (C-4″), 71.2 (C-3′), 69.9 (C-2′), 69.8 (*C*H$_2$), 67.8 (C-3″), 67.4 (C-2″), 64.7 (C-4′), 64.5 (C-5″), 62.1 (C-6′), 60.8 (C-6), 40.9, 29.2, 29.0, 26.0, 25.3, 21.4, 21.0, 20.6, 20.5, 20.4, 15.7; MALDIMS *m*/*z* calcd for [C$_{55}$H$_{68}$ClNO$_{26}$+Na]$^+$: 1286.3. Found: 1286.7.

3.16. 6-Aminohexyl 3,4,6-tri-*O*-acetyl-2-*O*-benzoyl-β-D-mannopyranosyl-(1→4)-[2,3,4-tri-*O*-acetyl-α-L-fucopyranosyl-(1→3)]-2-*O*-benzoyl-6-*O*-acetyl-β-D-glucopyranoside (21)

To a solution of **20** (317 mg, 0.25 mmol) in HOAc (5 mL) was added zinc powder (480 mg). The reaction mixture was stirred for 16 h at rt. After completion of the reaction, the mixture was filtered and the solids washed with CHCl$_3$. The filtrate was concentrated and purified by silica gel column chromatography (10:1, CHCl$_3$/CH$_3$OH) to give **21** (274 mg, quant): $[\alpha]_D^{23}$ −92.5 (*c* 1.0, CHCl$_3$); ^{1}H NMR (CDCl$_3$): δ 8.08–7.16 (m, 10H, 2*Ph*), 5.77 (d, 1H, $J_{2',3'} = 3.1$ Hz, H-2′), 5.51 (t, 1H, $J_{3',4'}$, $J_{4',5'} = 10.4$ Hz, H-4′), 5.37 (dd, 1H, $J_{2'',3''} = 3.1$ Hz, $J_{3'',4''} = 11.0$ Hz, H-3″), 5.29 (d, 1H, $J_{1'',2''} = 4.3$ Hz, H-1″), 5.26 (t, 1H, $J_{1,2\,2,3} = 8.6$ Hz, H-2), 5.23 (d, 1H, H-4″), 5.15 (dd, 1H, H-3′), 4.93 (dd, 1H, H-4″), 4.91 (s, 1H, H-1′), 4.85 (dd, 1H, H-5″), 4.78 (dd, 1H, $J_{5',6'a} = 3.1$ Hz, $J_{6'a,6'b} = 13.5$ Hz, H-6′a), 4.59 (dd, 1H, $J_{5,6a} = 2.5$ Hz, $J_{6a,6b} = 12.2$ Hz, H-6a), 4.41 (dd, 1H, H-6′b), 4.40 (d, 1H, H-1), 4.28 (dd, 1H, H-6b), 4.11 (t, 1H, $J_{3,4\,4,5} = 9.1$ Hz, H-4), 4.01 (t, 1H, H-3), 3.80 (dt, 1H, OC*H*$_2$CH$_2$), 3.73 (dt, 1H, H-5′), 3.61 (dt, 1H, H-5), 3.33 (dt, 1H, OCH$_2$C*H*$_2$), 2.62 (dd, 2H, C*H*$_2$NH), 2.23, 2.18, 2.043, 2.035, 2.02, 1.92, 1.91 (each s, 21H, 7Ac), 1.45–1.06 (m, 8H, 4C*H*$_2$), 0.61 (d, 3H, H-6″); ^{13}C NMR (CDCl$_3$): δ 170.5, 170.4, 170.2, 169.9, 169.8, 169.5, 165.9, 164.9, 133.6, 133.5, 129.9, 129.7, 129.41, 129.36 129.0, 128.6, 128.2, 100.9 (C-1), 100.8 (C-1′), 95.3 (C-1″), 79.3, 74.7, 74.0, 73.2, 71.6, 71.3, 70.0, 69.8, 67.53, 67.47, 64.8, 64.6, 62.2, 60.9, 39.8, 29.0, 28.0, 25.9, 25.1, 21.1, 20.71, 20.65, 20.61, 20.5, 15.8; MALDIMS *m*/*z* calcd for [C$_{52}$H$_{68}$NO$_{24}$+H]$^+$: 1090.4. Found: 1090.8.

3.17. Syntheses of multivalent glycoconjugate building blocks

3.17.1. Compound 23. To a solution of **21** (213 mg, 0.20 mmol) and 3-(*tert*-butoxycarbonyl-carboxymethylamino)-propionic acid 2,2,2-trichloroethylester **22** (81 mg, 0.22 mmol) in DMF (3 mL) were added Et$_3$N (60 μL, 0.43 mmol) and DEPC (36 μL, 0.24 mmol). The mixture was stirred for 16 h at rt. After completion of the reaction, the mixture was extracted with CHCl$_3$, washed with H$_2$O, dried (Na$_2$SO$_4$), and concentrated. The product was purified by silica gel column chromatography (3:1, toluene/acetone) to give **23** (186 mg, 66%): $[\alpha]_D^{23}$ −72.9 (*c* 1.0, CHCl$_3$); ^{1}H NMR (500 MHz, CDCl$_3$): δ 8.09–7.14 (m, 10H, 2*Ph*), 6.11 (t 1H, N*H*), 5.77 (d, 1H, $J_{2',3'} = 3.1$ Hz, H-2′), 5.51 (t, 1H, $J_{3',4'}$, $J_{4',5'} = 9.8$ Hz, H-4′), 5.37 (dd, 1H, $J_{2'',3''} = 3.0$ Hz, $J_{3'',4''} = 11.0$ Hz, H-3″), 5.29 (d, 1H, $J_{1'',2''} = 4.3$ Hz, H-1″), 5.26 (t, 1H, $J_{1,2\,2,3} = 7.9$ Hz, H-2), 5.23 (d, 1H, H-4″), 5.15 (dd, 1H, H-3′), 4.94 (dd, 1H, H-4″), 4.90 (s, 1H, H-1′), 4.87 (dd, 1H, H-5″), 4.77 (dd, 1H, $J_{5',6'a} = 3.0$ Hz, $J_{6'a,6'b} = 12.8$ Hz, H-6′a), 4.75 (s, 2H, C*H*$_2$CCl$_3$), 4.60 (dd, 1H, $J_{5,6a} = 2.4$ Hz, $J_{6a,6b} = 12.2$ Hz, H-6a), 4.40 (dd, 1H, H-6′b), 4.28 (d, 1H, H-1), 4.28 (dd, 1H, H-6b), 4.11 (t, 1H, $J_{3,4\,4,5} = 9.1$ Hz, H-4), 4.00 (t, 1H, H-3), 3.83 (s, 2H, NC*H*$_2$CO of β-alanine), 3.79 (dt, 1H, OC*H*$_2$CH$_2$ of sugar unit), 3.72 (dt, 1H, H-5′), 3.61 (m, 3H, H-5, NC*H*$_2$ of β-alanine), 3.33 (dt, 1H, OCH$_2$C*H*$_2$ of sugar unit), 3.00 (dd, 2H, C*H*$_2$NH of sugar unit), 2.77 (t, 2H, COCH$_2$ of β-alanine), 2.23, 2.18, 2.04, 2.03, 2.02, 1.92, 1.91 (each s, 21H, 7Ac), 1.47–1.06 (17H, m, *t*-Bu, 4(C*H*$_2$)), 0.62 (d, 3H, H-6″); ^{13}C NMR (CDCl$_3$): δ 170.4, 170.2, 170.1, 169.8, 169.7, 169.4, 169.0, 165.8, 164.8, 137.8, 133.5, 133.3, 129.9, 129.6, 129.33, 129.25 128.9, 128.5, 128.4, 128.1, 125.2, 100.8 (C-1), 100.7 (C-1′), 95.2 (C-1″), 94.7, 81.1, 79.2, 74.5, 74.0, 73.9, 73.13, 73.08, 71.5, 71.1, 69.9, 69.8, 67.5, 67.4, 64.7, 64.5, 62.1, 60.8, 52.4, 44.9, 39.1, 33.1, 29.1, 29.0, 28.2, 26.3, 25.3, 21.4, 21.0, 20.6, 20.4, 15.7; MALDIMS *m*/*z* calcd for [C$_{64}$H$_{83}$Cl$_3$N$_2$O$_{29}$+Na]$^+$: 1471.4. Found: 1471.5.

3.17.2. Compound 24. To a solution of **23** (186 mg, 0.13 mmol) in HOAc (2 mL) was added zinc powder (240 mg). The mixture was stirred for 1 h at rt and after completion of the reaction (TLC monitoring) the mixture was filtered through Celite. The filtrate was concentrated and purified by silica gel column chromatography (10:1, CHCl$_3$/CH$_3$OH) to give **24** (146 mg, 87%): $[\alpha]_D^{23}$ −76.0 (*c* 1.9, CHCl$_3$); ^{1}H NMR (500 MHz, CDCl$_3$): δ 8.08–7.17 (m, 10H, 2*Ph*), 6.45 (t 1H, N*H*), 5.77 (d, 1H, $J_{2',3'} = 3.1$ Hz, H-2′), 5.51 (t, 1H, $J_{3',4'}$, $J_{4',5'} = 9.8$ Hz, H-4′), 5.37 (dd, 1H, $J_{2'',3''} = 3.0$ Hz, $J_{3'',4''} = 11.0$ Hz, H-3″), 5.30 (d, 1H, $J_{1'',2''} = 3.7$ Hz, H-1″), 5.26 (t, 1H, $J_{1,2\,2,3} = 7.9$ Hz, H-2), 5.23 (d, 1H, H-4″), 5.16 (dd, 1H, H-3′), 4.94 (dd, 1H, H-4″), 4.91 (s, 1H, H-1′), 4.86 (dd, 1H, H-5″), 4.77 (dd, 1H, $J_{5',6'a} = 3.0$ Hz, $J_{6'a,6'b} = 12.8$ Hz, H-6′a), 4.60 (dd, 1H, $J_{5,6a} = 2.4$ Hz, $J_{6a,6b} = 12.2$ Hz, H-6a), 4.40 (dd, 1H, H-6′b), 4.28 (d, 1H, H-1), 4.28 (dd, 1H, H-6b), 4.11 (t, 1H, $J_{3,4\,4,5} = 9.1$ Hz, H-4) 4.01 (t, 1H, H-3), 3.88 (s, 2H, NC*H*$_2$CO of β-alanine), 3.79 (dt, 1H, OCH_2CH$_2$ of sugar unit), 3.72 (dt, 1H, H-5′), 3.61 (m, 3H, H-5, NCH_2 of β-alanine), 3.33 (dt, 1H, OCH$_2$CH_2 of sugar unit), 3.06 (dd, 2H, CH_2NH of sugar unit), 2.57 (t, 2H, COCH$_2$ of β-alanine), 2.23, 2.18, 2.04, 2.03, 2.02, 1.92, 1.91 (each s, 21H, 7Ac), 1.47–1.06 (17H, m, *t*-Bu, 4(CH_2)), 0.62 (d, 3H, H-6″); ^{13}C NMR (CDCl$_3$): δ 170.44, 170.36, 170.1, 169.9, 169.7, 169.4, 165.8, 165.0, 133.5, 133.4, 129.9, 129.6, 129.33, 129.2, 128.5, 128.4, 100.8 (C-1), 100.7 (C-1′), 95.2 (C-1″), 79.1, 77.2, 74.6, 73.9, 73.13, 73.08, 71.4, 71.2, 69.9, 69.8, 67.44, 67.38, 64.7, 64.5, 62.1, 60.8, 39.3, 29.0, 28.1, 26.2, 25.3, 21.0, 20.6, 20.54, 20.51, 20.41, 15.7; MALDIMS *m*/*z* calcd for $[C_{62}H_{82}N_2O_{29}+Na]^+$: 1341.5. Found: 1341.9.

3.18. Syntheses of dimeric glycoconjugate

3.18.1. Compound 25. To a solution of **24** (71 mg, 54 μmol) and **21** (65 mg, 59 μmol) in DMF (1.5 mL) were added Et$_3$N (15 μL, 108 μmol) and DEPC (9 μL, 59 μmol). The mixture was stirred for 16 h at rt. After completion of the reaction, the mixture was extracted with EtOAc, washed with H$_2$O, dried (Na$_2$SO$_4$), and concentrated. The product was purified by silica gel column chromatography (20:1, CHCl$_3$/CH$_3$OH) to give **25** (92 mg, 71%): $[\alpha]_D^{23}$ −98.0 (*c* 1.2, CHCl$_3$); ^{1}H NMR (500 MHz, CDCl$_3$): δ 8.09–7.29 (m, 20H, 4*Ph*), 5.78 (d, 2H, $J_{2',3'} = 3.1$ Hz, H-2′), 5.51 (t, 2H, $J_{3',4'}$, $J_{4',5'} = 9.8$ Hz, H-4′), 5.37 (dd, 2H, $J_{2'',3''} = 3.2$ Hz, $J_{3'',4''} = 11.0$ Hz, H-3″), 5.29 (d, 2H, $J_{1'',2''} = 3.7$ Hz, H-1″), 5.26 (t, 2H, $J_{1,2\,2,3} = 7.9$ Hz, H-2), 5.23 (d, 2H, H-4″), 5.15 (dd, 2H, H-3′), 4.94 (dd, 2H, H-4″), 4.91 (s, 2H, H-1′), 4.87 (dd, 2H, H-5″), 4.77 (dd, 2H, $J_{5',6'a} = 3.0$ Hz, $J_{6'a,6'b} = 12.8$ Hz, H-6′a), 4.60 (br dd, 2H, $J_{5,6a} = 2.4$ Hz, $J_{6a,6b} = 12.8$ Hz, H-6a), 4.40 (d, 2H, H-1), 4.39 (dd, 2H, H-6′b), 4.28 (dd, 2H, H-6b), 4.11 (t, 2H, $J_{3,4\,4,5} = 9.1$ Hz, H-4) 4.00 (t, 2H, H-3), 3.81–3.73 (m, 6H, 2H-5′, 2NCH_2CO of β-alanine, 2OCH_2CH$_2$ of sugar unit), 3.61 (br dd, 2H, H-5), 3.56 (br t, 2H NCH_2 of β-alanine), 3.33 (dt, 2H, OCH$_2$CH_2 of sugar unit), 3.00 (dd, 4H, CH_2NH of sugar unit), 2.37 (t, 2H, COCH_2 of β-alanine), 2.22, 2.18, 2.05, 2.04, 2.02, 1.92, 1.91 (each s, 42H, 14Ac), 1.47–1.06 (25H, m, *t*-Bu, 8(CH_2)), 0.62 (d, 6H, H-6″); ^{13}C NMR (CDCl$_3$): δ 170.4, 170.2, 170.1, 169.8, 169.7, 169.4, 169.0, 165.8, 164.9, 133.5, 133.3, 129.9, 129.6, 129.3, 129.2, 128.5, 128.4, 100.8 (C-1), 100.7 (C-1′), 95.2 (C-1″), 80.6, 79.2, 77.3, 74.5, 73.9, 73.12, 73.07, 71.4, 71.1, 69.9, 67.4, 67.3, 64.7, 64.5, 62.1, 60.8, 39.4, 39.1, 29.2, 26.3, 25.3, 21.0, 20.6, 20.54, 20.51, 15.7; MALDIMS *m*/*z* calcd for $[C_{114}H_{147}N_3O_{52}+Na]^+$: 2412.9. Found: 2413.3.

3.18.2. Compound 26. To a solution of **25** (90 mg, 37.6 μmol) in CH$_2$Cl$_2$ (1 mL) was added CF$_3$CO$_2$H (1 mL) and the mixture was stirred for 3 h at rt. After completion of the reaction, the mixture was concentrated and purified by silica gel column chromatography (10:1, CHCl$_3$/CH$_3$OH) to give **26** (74 mg, 86%). MALDIMS *m*/*z* calcd for $[C_{109}H_{139}N_3O_{50}+Na]^+$: 2312.8. Found: 2313.4.

3.19. Syntheses of trimeric glycoconjugate

3.19.1. Compound 27. To a solution of **26** (70 mg, 30.6 μmol) and **24** (44 mg, 33.7 μmol) in DMF (1 mL) were added Et$_3$N (9.1 μL, 66.0 μmol) and DEPC (5.5 μL, 36.0 μmol). The mixture was stirred for 16 h at rt. After completion of the reaction, the mixture was extracted with CHCl$_3$, washed with H$_2$O, dried (Na$_2$SO$_4$), and concentrated. The product was purified by silica gel column chromatography (30:1, CHCl$_3$/CH$_3$OH) to give **27** (85 mg, 79%): $[\alpha]_D^{23}$ −98.0 (*c* 2.6, CHCl$_3$); ^{1}H NMR (500 MHz, CDCl$_3$): δ 8.09–7.33 (m, 30H, 6*Ph*), 5.78 (d, 3H, $J_{2',3'} = 3.1$ Hz, H-2′), 5.51 (t, 3H, $J_{3',4'}$, $J_{4',5'} = 10.4$ Hz, H-4′), 5.37 (dd, 3H, $J_{2'',3''} = 3.7$ Hz, $J_{3'',4''} = 10.9$ Hz, H-3″), 5.29 (d, 3H, $J_{1'',2''} = 3.7$ Hz, H-1″), 5.25 (t, 3H, $J_{1,2\,2,3} = 7.9$ Hz, H-2), 5.23 (d, 3H, H-4″), 5.15 (dd, 3H, H-3′), 4.95 (dd, 3H, H-4″), 4.93 (s, 3H, H-1′), 4.87 (dd, 3H, H-5″), 4.77 (dd, 3H, $J_{5',6'a} = 3.0$ Hz, $J_{6'a,6'b} = 12.8$ Hz, H-6′a), 4.60 (br dd, 3H, $J_{5,6a} = 2.4$ Hz, $J_{6a,6b} = 12.8$ Hz, H-6a), 4.43 (d, 3H, H-1), 4.42 (dd, 3H, H-6′b), 4.28 (dd, 3H, H-6b), 4.12 (t, 3H, $J_{3,4\,4,5} = 9.1$ Hz, H-4) 4.00 (t, 3H, H-3), 3.83–3.75 (m, 8H, 3H-5′, 2NCH_2CO of β-alanine, 3OCH_2CH$_2$ of sugar unit), 3.67–3.57 (m, 5H, 3H-5, 2NCH_2 of β-alanine), 3.33 (dt, 3H, OCH$_2$CH_2 of sugar unit), 3.00 (dd, 6H, CH_2NH of sugar unit), 2.37 (t, 2H, COCH_2 of β-alanine), 2.23, 2.18, 2.05, 2.04, 2.02, 1.92, 1.91 (each s, 63H, 21Ac), 1.34–1.05 (33H, m, *t*-Bu, 12(CH_2)), 0.62 (d, 9H, H-6″); ^{13}C NMR (CDCl$_3$): δ 170.3, 170.2, 169.9, 169.7, 169.6, 169.3, 165.7, 164.7, 162.4, 133.4, 133.2, 129.8, 129.5, 129.20, 129.17, 128.4, 128.3, 100.8 (C-1), 100.5 (C-1′), 95.1 (C-1″), 79.1, 77.2, 74.5, 73.8, 73.0, 71.3, 71.1, 69.8, 67.34, 67.26, 64.6, 64.4, 62.0, 60.7, 39.2, 36.3, 31.2, 28.9, 28.1, 26.3, 25.2, 20.8, 20.5, 20.44, 20.39, 20.3, 15.5; MALDIMS *m*/*z* calcd for $[C_{171}H_{219}N_5O_{78}+Na]^+$: 3613.3. Found: 3613.0.

3.19.2. Compound 28. Compound **28** was derived from **27** according to the procedure described for the synthesis of **26**; yield: 60 mg (73%): MALDIMS *m*/*z* calcd for $[C_{166}H_{211}N_5O_{76}+Na]^+$: 3513.3. Found: 3512.8.

3.19.3. Compound 29. To a solution of **28** (24 mg, 6.88 μmol) and dansyl glycine (6.3 mg, 20.6 μmol) in DMF (1 mL) were added Et$_3$N (5.2 μL, 38.0 μmol) and DEPC (3.1 μL, 20.0 μmol) and the mixture was stirred for 16 h at rt. After completion of the reaction, the mixture was extracted with CHCl$_3$, washed with H$_2$O, dried (Na$_2$SO$_4$), and concentrated. The product was purified by silica gel column chromatography (30:1, CHCl$_3$/CH$_3$OH) to give dansyl derivative **29** (22 mg, 85%): $[\alpha]_D^{23}$ −74.4 (*c* 0.7, CHCl$_3$); ^{1}H NMR (500 MHz, CDCl$_3$): δ 8.09–7.27 (m, 36H, C$_{10}H_6$ of dansyl glycine, 6*Ph*), 5.29 (d, 3H, $J_{1'',2''} = 3.7$ Hz, H-1″), 4.93 (s, 3H, H-1′), 4.40 (d, 3H, $J_{1,2} = 7.9$ Hz, H-1), 3.97–3.54 (m, 15H, 3H-5, 3H-5′, 2NCH_2CO of β-alanine, 3OCH_2CH$_2$ of sugar unit, 2NCH_2 of β-alanine, NHCH_2CO of dansyl glycine), 3.33 (dt, 3H, OCH$_2$CH_2 of sugar unit), 3.00 (dd, 6H, CH_2NH of sugar unit), 2.89 (6H, s, N(CH_3)$_2$ of dansyl glycine), 2.77 (t, 2H, COCH_2 of β-alanine), 2.23, 2.18, 2.05, 2.04, 2.02, 1.92, 1.91 (each s, 63H, 21Ac), 1.34–1.05 (24H, m, 12(CH_2)), 0.61 (d, 9H, H-6″); ^{13}C NMR (CDCl$_3$): δ 170.5, 170.3, 170.1, 169.9, 169.7, 169.4, 165.8, 164.9, 133.6, 133.4, 129.9, 129.6, 129.3, 128.9, 128.5, 100.9 (C-1), 100.7 (C-1′), 95.3 (C-1″), 79.2, 74.6, 74.0, 73.1, 71.5, 71.2, 70.0, 67.5, 67.4, 64.7, 64.5, 62.2, 60.9, 45.4, 39.4, 28.9, 26.4, 25.3, 21.0, 20.7, 20.6, 20.5, 15.7; MALDIMS *m*/*z* calcd for [C$_{180}$H$_{225}$N$_7$O$_{79}$S+Na]$^+$: 3802.4. Found: 3802.7.

3.19.4. Compound 2. Compound **2** was synthesized from **29** according to the procedure described for the synthesis of **1**; yield: 11 mg (91%): $[\alpha]_D^{23}$ −61.3 (*c* 0.4, CH$_3$OH/H$_2$O 1:1); ^{1}H NMR (500 MHz, 1:1 CD$_3$OD/D$_2$O): δ 8.54–7.35 (m, 6H, C$_{10}H_6$ of dansyl glycine), 5.46 (d, 3H, $J_{1'',2''} = 3.7$ Hz, H-1″), 4.56 (br d, 3H, H-1′), 4.36 (br d, 3H, H-1), 2.88, 2.87 (6H, each s, N(CH_3)$_2$ of dansyl glycine), 1.18 (d, 9H, H-6″); ^{13}C NMR (125 MHz, 1:1 CD$_3$OD/D$_2$O): δ 174.0, 171.1, 170.8, 170.1, 152.4, 135.5, 131.3, 130.5, 130.4, 129.6, 124.7, 120.2, 120.1, 116.8, 103.5, 100.3, 99.8, 79.5, 78.6, 78.1, 76.4, 75.7, 75.3, 74.1, 73.3, 72.9, 71.7, 71.3, 71.1, 70.6, 69.8, 68.3, 68.1, 62.7, 61.8, 61.5, 52.5, 49.4, 45.9, 45.4, 44.9, 40.4, 30.0, 29.6, 27.1, 26.1, 16.7; MALDIMS *m*/*z* calcd for [C$_{96}$H$_{159}$N$_7$O$_{52}$S+Na]$^+$: 2298.0. Found: 2297.6.

3.20. Syntheses of tetrameric glycoconjugate

3.20.1. Compound 30. Compound **30** was synthesized from **28** according to the procedure described for the synthesis of **25**; yield: 42 mg (83%): $[\alpha]_D^{23}$ −99.0 (*c* 1.0, CHCl$_3$); ^{1}H NMR (500 MHz, CDCl$_3$): δ 8.08–7.27 (m, 40H, 8*Ph*), 5.78 (d, 4H, $J_{2',3'} = 3.1$ Hz, H-2′), 5.51 (t, 4H, $J_{3',4'}$, $J_{4',5'} = 10.4$ Hz, H-4′), 5.37 (dd, 4H, $J_{2'',3''} = 3.7$ Hz, $J_{3'',4''} = 10.9$ Hz, H-3″), 5.29 (d, 4H, $J_{1'',2''} = 3.7$ Hz, H-1″), 5.28 (t, 4H, $J_{1,2\,2,3} = 7.9$ Hz, H-2), 5.23 (d, 4H, H-4″), 5.15 (dd, 4H, H-3′), 4.95 (dd, 4H, H-4″), 4.91 (s, 4H, H-1′), 4.85 (dd, 4H, H-5″), 4.77 (dd, 4H, $J_{5',6'\mathrm{a}} = 3.0$ Hz, $J_{6'\mathrm{a},6'\mathrm{b}} = 12.8$ Hz, H-6′a), 4.60 (br dd, 4H, $J_{5,6\mathrm{a}} = 2.4$ Hz, $J_{6\mathrm{a},6\mathrm{b}} = 12.8$ Hz, H-6a), 4.41 (d, 4H, H-1), 4.40 (br d, 4H, H-6′b), 4.28 (br d, 4H, H-6b), 4.11 (t, 4H, $J_{3,4\,4,5} = 9.1$ Hz, H-4) 4.00 (t, 4H, H-3), 3.83–3.75 (m, 10H, 4H-5′, 2NCH_2CO of β-alanine, 4OCH_2CH$_2$ of sugar unit), 3.67–3.57 (m, 6H, 4H-5, 2NCH_2 of β-alanine), 3.33 (dt, 4H, OCH$_2$CH_2 of sugar unit), 3.00 (dd, 8H, CH_2NH of sugar unit), 2.37 (t, 2H, COCH_2 of β-alanine), 2.22, 2.18, 2.04, 2.03, 2.02, 1.92, 1.91 (each s, 84H, 28Ac), 1.35–1.04 (41H, m, *t*-Bu, 16(CH_2)), 0.62 (d, 12H, H-6″); ^{13}C NMR (CDCl$_3$): δ 170.5, 170.3, 170.1, 169.8, 169.7, 169.4, 165.8, 164.9, 133.6, 133.4, 129.9, 129.6, 129.4, 129.3, 128.6, 128.5, 100.9 (C-1), 100.7 (C-1′), 95.3 (C-1″), 79.2, 74.6, 74.0, 73.2, 73.1, 71.5, 71.2, 70.0, 67.5, 67.4, 64.7, 64.5, 62.2, 60.9, 39.4, 39.2, 28.22, 28.17, 26.5, 26.4, 25.4, 21.0, 20.7, 20.61, 20.57, 20.5, 15.7; MALDIMS *m*/*z* calcd for [C$_{228}$H$_{291}$N$_7$O$_{104}$+Na]$^+$: 4813.8. Found: 4814.0.

3.20.2. Compound 31. Compound **31** was synthesized from **30** according to the procedure described for the synthesis of **26**; yield: 24 mg (56%); MALDIMS *m*/*z* calcd for [C$_{223}$H$_{283}$N$_7$O$_{102}$+Na]$^+$: 4713.7. Found: 4713.9.

3.20.3. Compound 32. Compound **32** was synthesized from **31** according to the procedure described for the synthesis of **29**; yield: 24 mg (94%): $[\alpha]_D^{23}$ −85.0 (*c* 0.8, CHCl$_3$); ^{1}H NMR (500 MHz, CDCl$_3$): δ 8.09–7.27 (m, 46H, C$_{10}H_6$ of dansyl glycine, 8*Ph*), 5.28 (d, 4H, $J_{1'',2''} = 3.7$ Hz, H-1″), 4.92 (s, 4H, H-1′), 4.42 (d, 4H, $J_{1,2} = 7.9$ Hz, H-1), 3.97–3.54 (m, 20H, 4H-5, 4H-5′, 2NCH_2CO of β-alanine, 4OCH_2CH$_2$ of sugar unit, 4NCH_2 of β-alanine, NHCH_2CO of dansyl glycine), 3.33 (dt, 4H, OCH$_2$CH_2 of sugar unit), 3.00 (dd, 8H, CH_2NH of sugar unit), 2.89 (6H, s, N(CH_3)$_2$ of dansyl glycine), 2.77 (t, 2H, COCH_2 of β-alanine), 2.23, 2.18, 2.05, 2.04, 2.02, 1.92, 1.91 (each s, 84H, 28Ac), 1.34–1.05 (32H, m, 16(CH_2)), 0.61 (d, 12H, H-6″); ^{13}C NMR (CDCl$_3$): δ 170.5, 170.3, 170.1, 169.9, 169.7, 169.5, 165.8, 164.9, 133.6, 133.4, 129.9, 129.6, 129.3, 128.6, 128.5, 100.9 (C-1), 100.7 (C-1′), 95.3 (C-1″), 79.2, 74.6, 74.0, 73.1, 71.5, 71.2, 70.0, 67.5, 67.4, 64.7, 64.5, 62.2, 60.9, 39.4, 29.7, 29.2, 29.1, 26.41, 26.35, 25.4, 21.0, 20.7, 20.6, 20.5, 15.7; MALDIMS *m*/*z* calcd for [C$_{237}$H$_{297}$N$_9$O$_{105}$S+Na]$^+$: 5003.4. Found: 5003.9.

3.20.4. Compound 3. Compound **3** was synthesized from **32** according to the procedure described for the synthesis of **2**; yield: 13.6 mg (91%): $[\alpha]_D^{23}$ −55.8 (*c* 0.5, CH$_3$OH/H$_2$O 1:1); ^{1}H NMR (500 MHz, CDCl$_3$): δ 8.39–7.28 (m, 6H, C$_{10}H_6$ of dansyl glycine), 5.42 (br t, 4H, H-1″), 4.53 (br d, 4H, H-1′), 4.33 (d, 4H, $J_{1,2} = 7.9$ Hz, H-1), 2.84, 2.83 (6H, each s, N(CH_3)$_2$ of dansyl glycine), 1.18 (d, 9H, H-6″); ^{13}C NMR (125MHz, 1:1 CD$_3$OD/D$_2$O): δ 103.4, 100.4, 99.7, 79.3, 79.0, 78.0, 76.4, 75.7, 75.3, 74.4, 73.3, 72.9, 71.7, 71.3, 70.6, 69.7, 68.3, 68.1, 62.7, 61.7, 61.5, 46.0, 40.4, 30.0, 29.6, 27.2, 27.1, 26.1, 16.7; MALDIMS *m*/*z* calcd for [C$_{125}$H$_{209}$N$_9$O$_{69}$S+Na]$^+$: 2995.3. Found: 2995.0.

Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.carres.2006.04.019.

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